Volume 37 May, 1951 *Number 5*

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A Technical Publication Devoted to the Selection and Use of Lubricants

THIS ISSUE

AIRCRAFT
ENGINE OIL
SYSTEMS

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LUBRICATION

A TECHNICAL PUBLICATION DEVOTED TO THE SELECTION AND USE OF LUBRICANTS

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Vol. XXXVII May, 1951 No. 5

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Aircraft Engine Oil Systems

SUCCESSFUL lubrication of aircraft engines depends upon engine design, oil quality and the design of the external oil system. The part played by oil quality has been discussed in magazine "Lubrication" in the past.[1] Various papers have covered the design of the external oil system for better altitude performance and improved oil defoaming. However, comparatively little information has been written on the serious nature of water accumulations and dilution problems as related to the design of the external oil system.

Service problems such as difficult starting, master rod bearing failures, sludge and water accumulations, ice formation in oil lines and breather lines, loss of oil pressure and foaming may be traceable to the design of oil systems.

As aircraft increase in size and in number of engines per aircraft, they become more complex and less accessible for servicing. Large numbers of aircraft now in operation, as well as size, make it more difficult to provide hangar facilities, and provisions therefore must be made to enable starting of engines after standing unprotected at low temperatures. In military operations particularly, rapid starting and adequate engine lubrication are essential without preheating. In commercial operations there is normally time available for preheating of engines prior to a scheduled flight.

In addition to extreme cold temperatures that exist at starting on the ground, there are severe conditions encountered at extremely high altitude. Perhaps the most severe in flight are found at altitudes in excess of 40,000 feet where outside air temperatures may run below minus 100°F. Long flights and low atmospheric pressures at these altitudes impose critical conditions on the oil system that do not exist at lower altitudes. It is the purpose of this discussion to touch briefly on some of these problems for the benefit of both operators and designers.

INTERNAL OIL SYSTEMS

Wet Sump

Two types of oil circulating systems are currently used in reciprocating aircraft engines, the wet sump and the dry sump. The wet sump, as the name implies, carries its oil supply in the engine sump or crankcase in the same manner as commonly found in automotive engines.

A typical example of a wet sump system may be found in any of the popular 4 and 6 cylinder horizontally opposed aircraft engines (Figure 1). In this system, oil is drawn from the crankcase to the pressure pump and delivered under pressure to crankshaft and camshaft bearings, valve tappet guides and the accessory section. When oil pressure exceeds a predetermined value a pressure relief valve opens and returns a portion of the oil supply to the inlet side of the pump. This prevents the

[1] Magazine Lubrication, September 1941, "Aircraft Engine Lubrication."

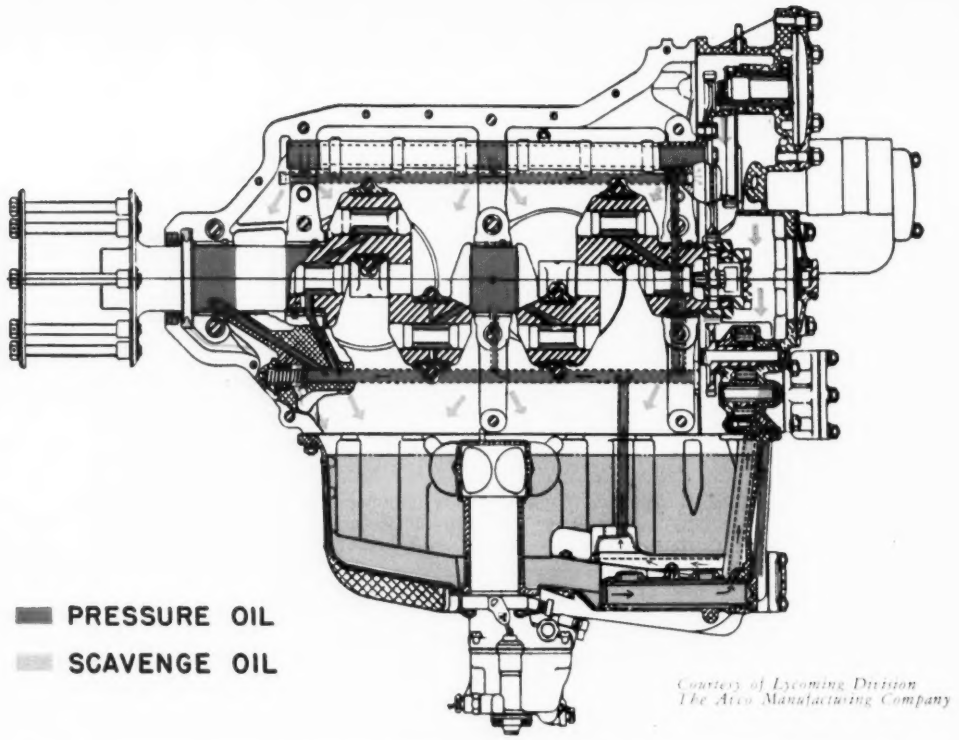


Figure 1 — Lubrication system of Lycoming horizontally opposed Direct Drive 4 cylinder Aircraft Engine. A typical example of wet sump oil system in smaller aircraft engines.

build-up of excessive pressure and possible damage to certain parts of the oil system.

The first route taken by oil is to each main bearing, not only to lubricate and cool those bearings, but also to transfer oil into the drilled passages of the crankshaft through an annulus in each bearing and drilled passages in the crankshaft. In this manner, oil is delivered under pressure to each connecting rod bearing from which the excess is thrown off to lubricate cylinders, pistons, piston rings and piston pin bushings.

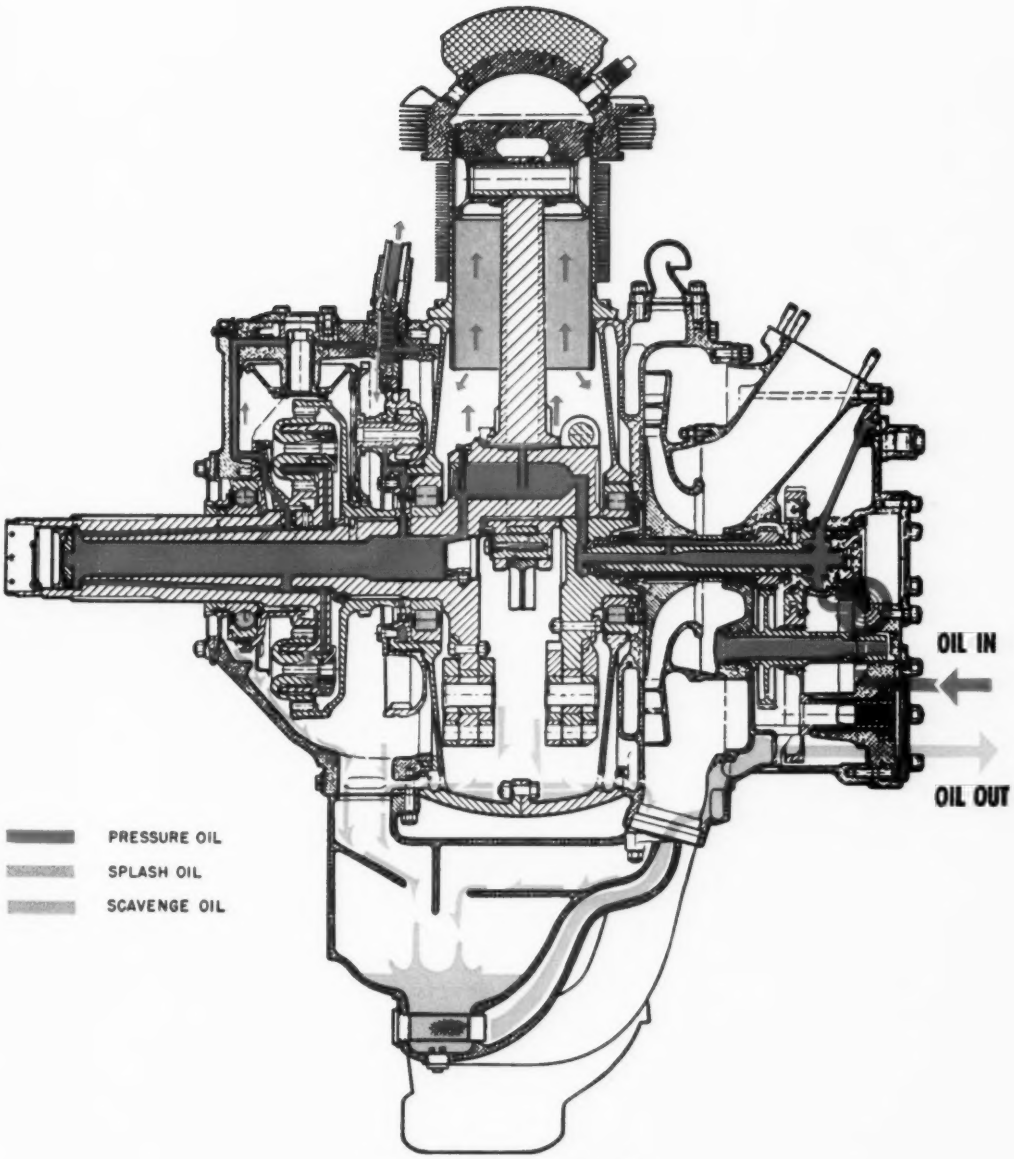
The second route is to camshaft bearings and valve tappet guides. Most engines have drilled passages in guides and tappets that match up at intervals during each stroke to introduce a metered quantity into the center of the tappet where it is forced through hollow push rods and drilled passages in rocker arms to lubricate the valve gear assembly. The excess thrown from the rocker arm bearings serves to lubricate and cool valve stems and finally drains back into the crankcase either through push rod housings or oil drain lines. The third route supplies oil to the bushings and gears of the accessory section.

The principal advantages of the wet sump system are low cost and simplicity. This system has definite limitations that make it unsuited for larger engines, particularly radial or inverted in-line types. Furthermore, this system is unsatisfactory for unusual flight maneuvers such as prolonged dives and steep climbs and, of course, is unsuited for inverted flight.

Oil temperatures in the wet sump system frequently run at much higher levels than the dry sump system because of the problem of cooling the scavenge oil. Higher temperatures therefore may cause increased rates of oil deterioration and shorter bearing life.

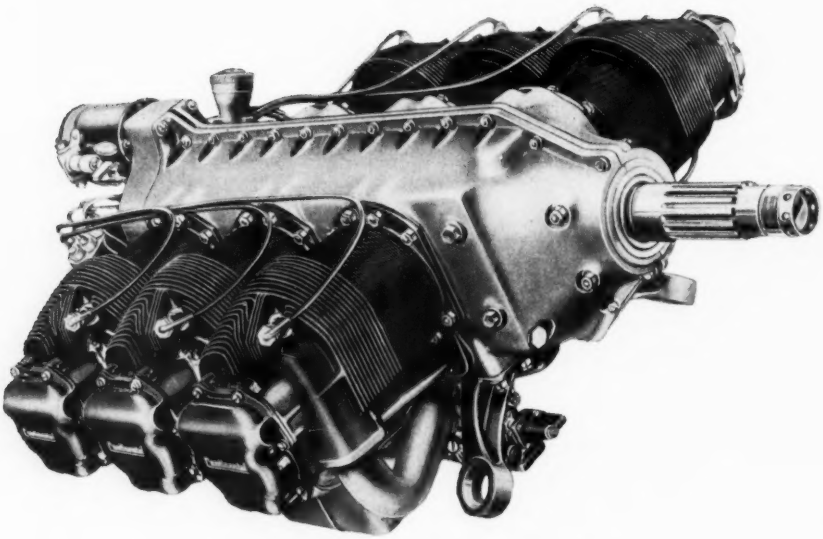
Dry Sump

The dry sump system is used universally in larger types of reciprocating engines, such as horizontally opposed, inverted in-line, "V" type and all radial engines. In the conventional system the oil supply is carried in an external tank and all oil delivered to the engine comes directly from the tank; scavenge or return oil is collected in sumps and pumped back to the tank. The chief advantages of the dry sump system are found in the flexibility afforded the designer in the location and size of the oil tank. This feature greatly simplifies engine design, installation and cowling design and permits better oil



Courtesy of Wright Aeronautical Corp.

Figure 2 — Longitudinal section through Wright 9 cylinder Radial Aircraft Engine showing oil circulation in a dry sump type of oil system.



Courtesy of Continental Motors Corp.

Figure 3 — Continental model E-185. Horizontally Opposed 6 cylinder Air Cooled Engine.

cooling. Unusual maneuvers also are possible with a properly designed dry sump system without the danger of interruptions in the oil supply and for these reasons contribute to engine reliability and safety. It will be seen from the subsequent discussion describing the external parts of the oil system that good oil temperature control is possible and this in turn reduces the rate of oil deterioration.

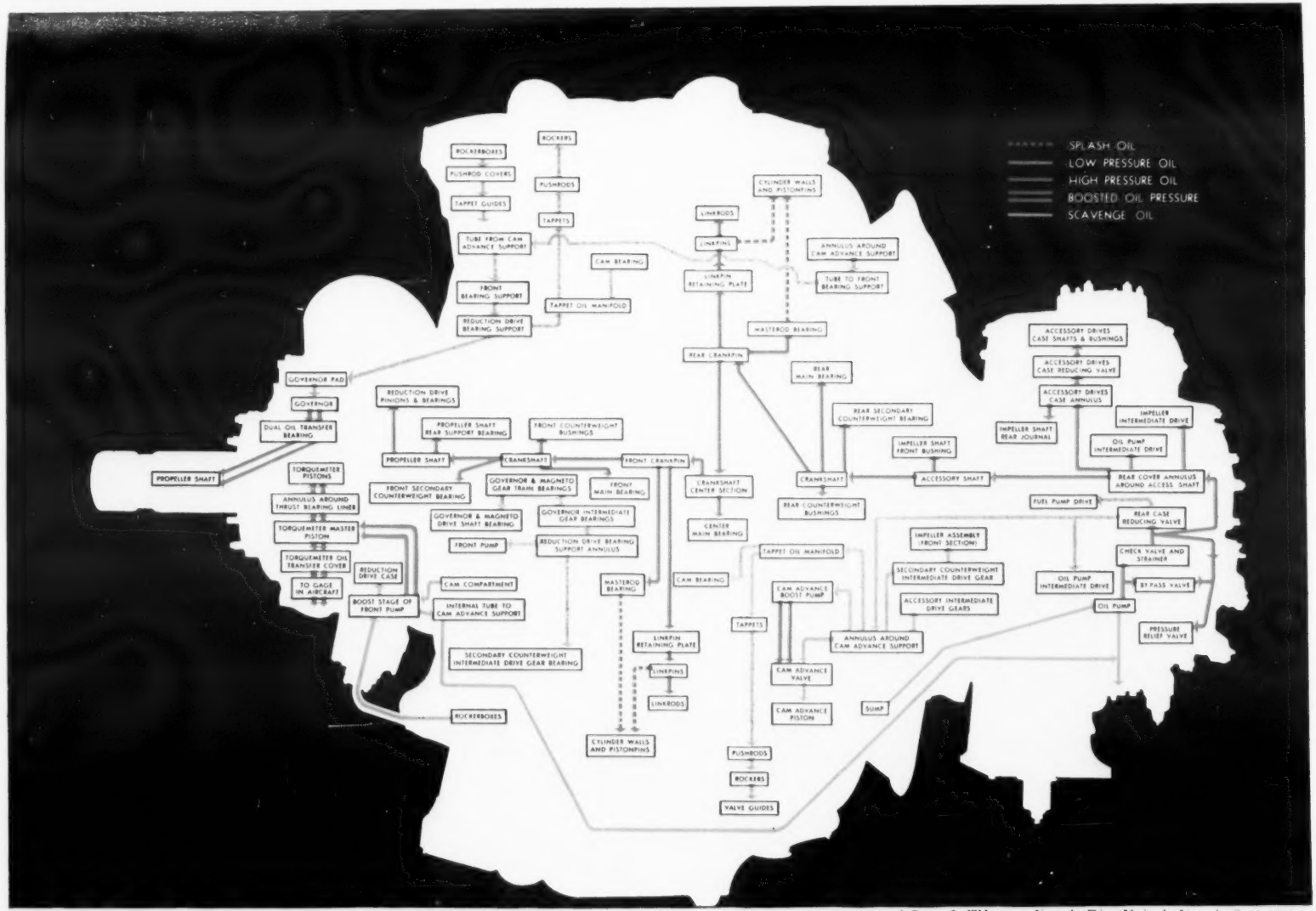
An example of a typical dry sump system may be found in a single row radial engine (Figure 2). Basically the two-row and four-row radial aircraft engines are similar to the single row engine insofar as the lubrication system is concerned. For reasons of simplicity this discussion will be confined to the single row radial engine. In this type of engine, oil enters the pressure pump from an external supply tank, is distributed through various routes or branches to different parts of the engine and finally is picked up by one or more scavenge pumps, circulated through an oil cooler and returned to the supply tank. A description of this system may be divided into three parts; the rear case or accessory section, the power section or crankcase and the nose or front section.

In the rear case, oil first passes through the pressure pump and then to a strainer and a pressure relief valve. The function of this relief valve is to return a portion of the oil flow to the pump inlet to prevent a build-up of excessive oil pressure under certain conditions of operation. Some engines also have a thermostat in the pressure relief valve to delay the opening when engine oil is cold and viscous in order to increase the supply of oil to vital parts such as master rod bearings, cylinders, etc. All oil first passes through the fine mesh strainer whose function is to remove solid material that might otherwise be abrasive to engine parts or clog oil passages. A bypass valve is provided to prevent collapse and damage of strainer when oil is cold or when the strainer may be clogged. A check valve usually is located downstream to prevent oil draining from the tank into the engine during periods when the engine is not in operation. From the oil strainer, the circulation of oil divides into several different routes. The major quantity of oil enters the accessory drive or starter shaft through the bushing annulus at the rear end. In passing through the accessory drive shaft to the end of the crankshaft, some of the oil is bled off through drilled passages to lubricate the impeller shaft bushings. The second route of oil circulation in the rear case is through drilled passages or oil lines to various accessory drive bushings. On engines with two speed blowers, oil from this section is supplied to a selector valve for operation of high and low speed blower clutches.

All of the oil supplied to the power section is through drilled passages in the crankshaft. In engines with plain type main bearings, the oil supply comes from the center of the shaft through a drilled hole in the main journal. Some engines also supply a limited quantity of oil through drilled passages in the cheeks of the crankshaft for the lubrication of the floating damper pin bushings.

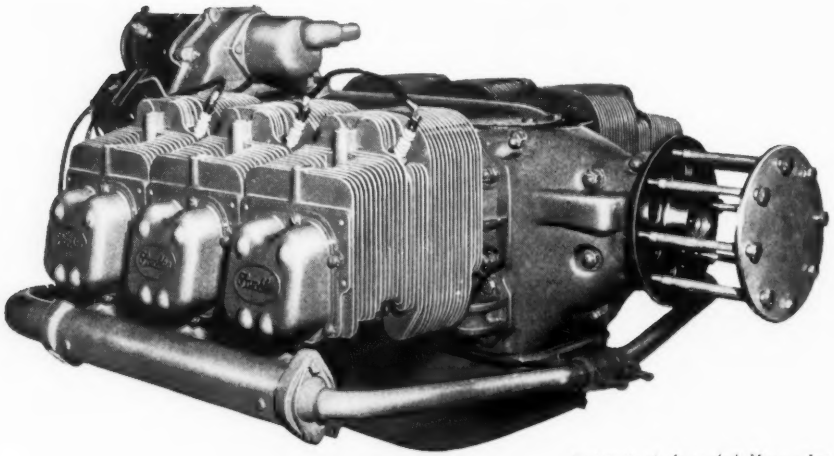
The largest quantity of oil is supplied to the master rod bearing and knuckle pin bushings. The excess or oil thrown off these parts sprays against the cylinders, pistons, rings and piston pins.

Some engines have jets in the crankshaft which



Courtesy of Pratt & Whitney Aircraft Div. United Aircraft Corporation

Figure 4 — Schematic diagram of Internal Oil System of 2 Row Radial Aircraft Engine.



Courtesy of Aircooled Motors Inc.

Figure 5 — Franklin model 6A4-165B3 Horizontally Opposed 6 cylinder Air Cooled Engine.

meter oil to cylinders and pistons. Other engines rely upon the oil thrown off the master rod bearings and knuckle pins to lubricate and cool the pistons and cylinders. In those engines with roller bearing type of main bearings, lubrication is afforded by spray from the master rod bearing and in some cases from the damper pin bushings.

High pressure oil enters the nose section through the crankshaft front extension. In the nose section, the oil supply normally divides into two or three routes depending upon whether the engine has reduction gears and a Hydromatic propeller. The first route is to the cam mechanism. Oil is transferred from the crankshaft to the front section of the main crankcase, usually through part of the cam mechanism, and finally to the cam drive gear and pinion bushing and to the cam bearing and also to the oil sump pump drive gear bushing.

The second route in the nose section is to the planetary reduction gears. This route normally is through the center of the propeller shaft that rotates on the crankshaft front extension and through drilled passages to each of the spider arm bushings or through drilled passages in the propeller shaft pinion supporting flange and pinion bushings. A spray of oil from fixed jets and from pinion gear bushings serves to lubricate the planetary reduction gear.

The third route of lubricating oil is to the Hydromatic propeller governer, if installed in the engine, and finally to the valve tappet guides where a metered supply passes up each push rod through drilled passages to rocker arms for lubrication of rocker arm bearings and for the lubrication and cooling of valve stems. On an engine equipped with a Hydromatic propeller, the oil is transferred back into the propeller shaft by means of oil transfer rings where it may be used for the operation of this type of propeller. Oil pressure may be boosted in some engines for operation of Hydromatic propellers.

Engine oil may be scavenged from the engine by one or more separate scavenge pumps. Ordinarily oil from the rear section and the power section is drained into a sump located on the lower side of the engine and picked up by a main scavenge pump and returned to the oil tank. In some engines, separate scavenge pumps are provided for the nose case, each row of cylinders, and rocker boxes. Usually the rocker boxes of cylinders located below the horizontal center line of the engine are interconnected and drain into a sump while the rocker boxes of those cylinders above the horizontal center line of the engine may drain into one of the cases through the push rod housings.

EXTERNAL OIL SYSTEM

Requirements

The general requirements of an external oil system are listed below:

1. The capacity of the oil tank must be sufficient to allow operation to the extreme range of the aircraft. In addition a large enough expansion space must be provided above the filler neck level for the build up of a normal amount of oil foam without any overflow through the vent.
2. An adequate flow of oil to the engine must be assured under all conditions of flight that is free of injurious foreign matter.
3. If provided with a dilution system an accurate control on quantity of fuel dilution must be exercised. If a hopper tank is used a dependable

means must be provided for segregation of diluted oil in the hopper from bulk oil in the balance of the tank. Also it must be capable of rapid warming up of the bulk oil after starting.

4. The system should be capable of maintaining control of temperature of oil both in the tank and the oil entering the engine under all expected altitudes, outside air temperatures, air speeds and angles of climb.
5. Means must be provided to separate entrained air as rapidly as possible at all expected altitudes.
6. Excessive oil pressures on the oil cooler due to cold oil must be avoided to prevent rupture of the cooler.
7. If a Hydromatic propeller is used a reserve must be provided in the bottom of the tank for propeller feathering.

Description

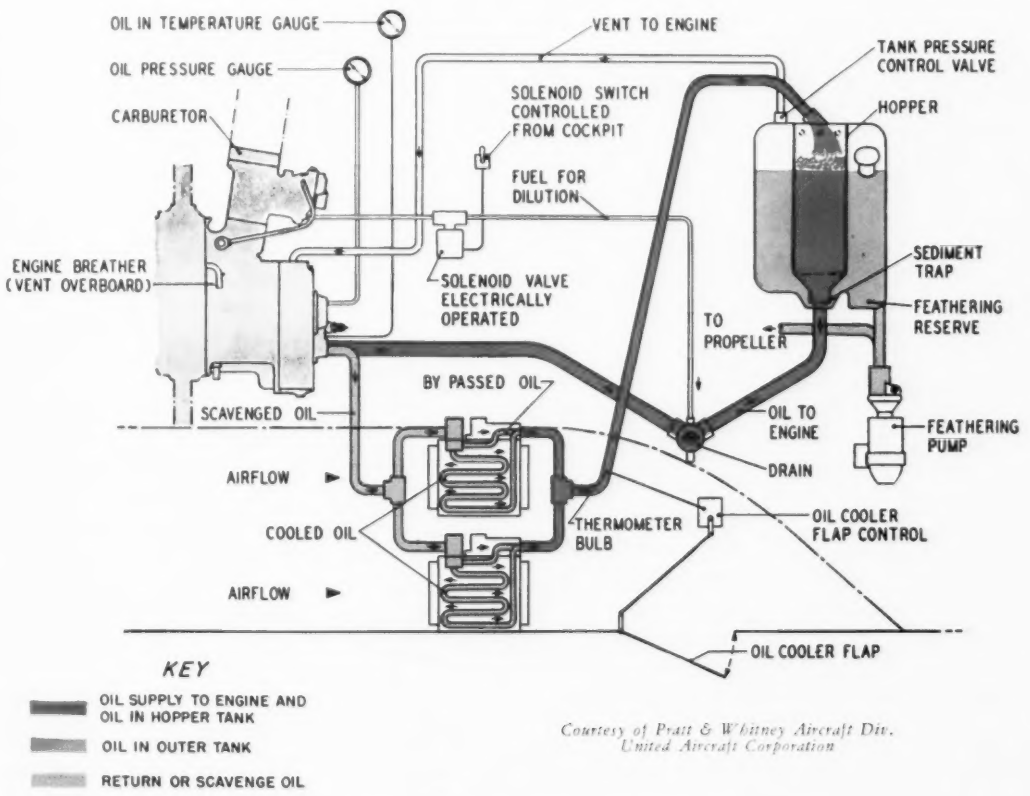
In a conventional external oil system (Figure 6), scavenge oil first passes a thermostatic valve or regulator, an oil cooler, a thermostatic switch to control cooler flap operation and finally returns to the oil tank. The operation of the thermostatic valve normally installed on the oil cooler may be described in three steps (Figure 7). First, immediately after starting a cold engine the viscosity of cold oil causes a build-up of high pressure in the scavenge line. In order to protect the oil cooler from rupture under such conditions, a surge valve opens when the pressures normally reach about 60-70 psi allowing oil to bypass both thermostatic valve and cooler and return directly to the oil tank.

Secondly, as oil warms up and its viscosity drops, the pressure in the scavenge line also drops allowing the surge valve to close and a bypass valve to open permitting oil to circulate around the core of the cooler, warming oil that may be congealed inside the cooler. The opening pressure of the bypass valve may be set to approximately 40 psi.

The third step takes place when oil in the system has warmed up sufficiently to enable the oil cooler thermostatic valve to close causing oil to circulate through cooler core where it is cooled to the desired temperature.

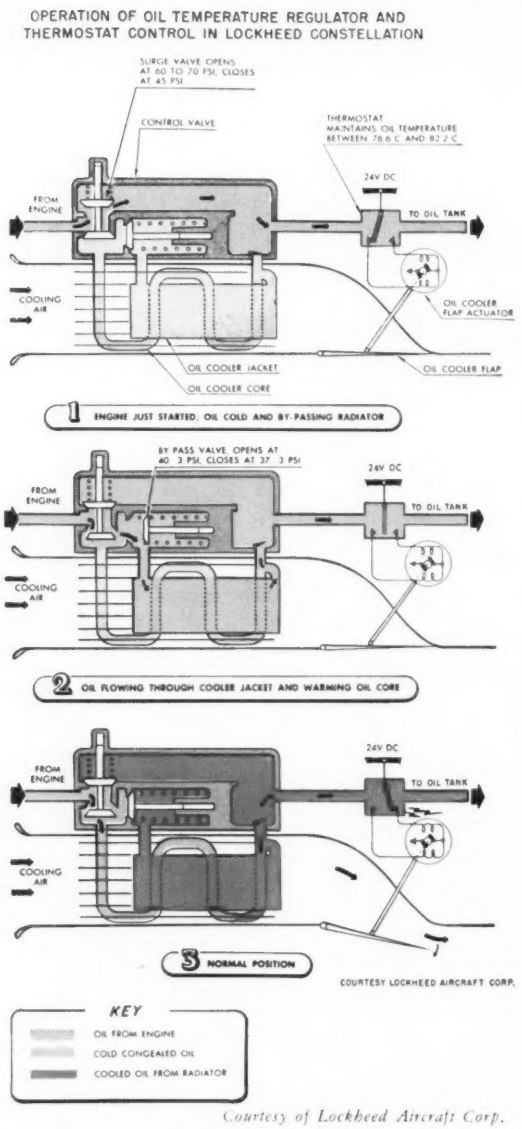
Oil Coolers

One of the principal functions of lubricating oil in an aircraft engine is to serve as a coolant. Because of the large rate of heat rejection to the oil, heat must be removed before oil returns to the engine.



Courtesy of Pratt & Whitney Aircraft Div. United Aircraft Corporation

Figure 6 — Typical External Lubrication System with Hopper Type Oil Tank.


OPERATION OF OIL TEMPERATURE REGULATOR AND THERMOSTAT CONTROL IN LOCKHEED CONSTELLATION
SURGE VALVE OPENS AT 60 TO 70 PSI, CLOSES AT 45 PSI
CONTROL VALVE
THERMOSTAT MAINTAINS OIL TEMPERATURE BETWEEN 76.6 C AND 82.2 C
24V DC
FROM ENGINE
TO OIL TANK
COOLING AIR
OIL COOLER FLAP ACTUATOR
OIL COOLER JACKET
OIL COOLER CORE
OIL COOLER FLAP
1 ENGINE JUST STARTED, OIL COLD AND BY-PASSING RADIATOR
BY PASS VALVE OPENS AT 40 3 PSI, CLOSES AT 37 3 PSI
2 OIL FLOWING THROUGH COOLER JACKET AND WARMING OIL CORE
3 NORMAL POSITION
COURTESY LOCKHEED AIRCRAFT CORP.
KEY
OIL FROM ENGINE
COLD CONGEALED OIL
COOLED OIL FROM RADIATOR

Courtesy of Lockheed Aircraft Corp.

Figure 7 — Three Steps Showing Operation of The Oil Temperature Regulator and Thermostat Control Valve in Lockheed Constellation.

The conventional method at the present time is to install the cooler on the scavenge or return line so that oil is cooled before entering the oil tank. To provide for the wide extremes of outside air temperature, variations in air speed and changes in the rate of heat rejection, some control of air flow through the cooler is essential. Early designs attempted to regulate only the quantity of oil passing through the cooler but were less successful than by controlling air flow for the simple reason that once oil had congealed in the cooler in flight it would be difficult to warm it up and re-establish oil flow unless it was possible to operate at warmer outside air temperatures. One of the most successful installations from a reliability point of view consists of a thermostat in the oil line to operate an actuator connected to a cooler flap. With such an arrangement, oil temperatures can be controlled automatically by the flap position and oil temperature regulator valve to meet any change in operating conditions. Most of these systems also have provisions for a manual over-ride control if desired.

Having thus cooled the scavenge oil from an average temperature of 230-240°F. as it leaves the engine down to an average of about 170°F., the scavenge oil finally is returned to the tank.

Oil Tanks

The oil tank in most modern installations serves not only as an oil reservoir but also to de-aerate. Many of the present oil tanks contain a hopper in the center. This is usually a smaller cylindrical tank mounted inside of the main tank. Return oil from the engine is introduced into the top of the hopper in a tangential manner imparting a swirling or rotary motion to the oil which aids materially in the separation of entrained air.

In the dry sump system the combined capacities of the scavenge pumps will be from two to three times the capacity of the pressure pump. This large excess capacity has been found necessary to assure complete scavenging under various flight conditions. As a result, large quantities of air or vapor from the different cases is mixed with the engine oil and must be separated prior to its reuse in the engine again and this takes place in the oil tank.

In the hopper system the rate of oil warm-up is much faster since only a relatively small quantity of oil is utilized for engine operation. The circulation of warm oil through the hopper tank gradually warms up the oil in the remainder of the tank and feeds into the hopper as the oil in the latter is consumed.

On aircraft equipped with Hydromatic propellers, a reservoir must be provided to maintain a reserve supply of oil for propeller feathering in the event that the main supply of oil in the tank had been consumed and it was necessary to shut down the engine in flight.

The most important problems encountered in the design of conventional oil systems are first, loss of oil pressure at altitude and second, air entrainment. A considerable amount of design effort usually goes into every new oil system to overcome these problems. Experience has shown that a majority of lubrication failures can be traced to loss of oil pressure and in turn to the system design. It should be quite evident that if the supply of oil, for one reason or another, is inadequate the pressure pump cannot

overcome such a condition. Low oil pressure and engine failure are bound to occur.

All oil pumps have a critical altitude above which the volumetric efficiency falls rapidly. This critical altitude is a function of the absolute oil pressure at the pump inlet. The latter is affected by pressure drop in oil inlet lines and any losses at the pump entrance itself. The basic design of the pump also is important. Much progress has been made to reduce these losses to a minimum.

The size of scavenge pumps is a compromise. As mentioned above, their combined capacities is two to three times the pressure pump capacity. Anything smaller may fail to scavenge at all times and result in loading up the engine. Anything much larger contributes to excessive air entrainment or foaming and increase the difficulties of air separation.

Even with the optimum conditions of pump design, low line losses and excellent air separation in the tank, definite limits of altitude may be reached. Several new systems have been developed for such conditions with promising results, the hot tank system, pressurized tank and the closed circuit system. Complete descriptions may be found in various papers such as "Factors in Aeration and Dearation of Aircraft-Engine Oil" by W. L. Weeks, SAE Journal, April 1946 and "High Altitude Aircraft Oil Systems" by F. E. Carroll, Jr., SAE Journal, October 1950.

The above papers point out the necessity of changing to one of the newer oil systems if successful engine lubrication is to be achieved at high altitudes. Also one of the new methods of improved dearation is essential to overcome problems of low oil pressure.

Oil Dilution

Aircraft engine oil like any other high grade oil increases in viscosity with a decrease in temperature. Because of the necessity of using a high viscosity grade in larger aircraft engines the limit in starting temperature is reached much sooner than in automotive practice using oils of much lower viscosity. For example a viscosity of 35,000 seconds (Saybolt Universal) is reached at a temperature of plus 25°F. with aircraft engine oil grade 100 (military designation grade 1100) whereas the same viscosity is reached at a temperature of minus 25°F. approximately with an SAE 10 grade of motor oil. Thus we see that starting problems of the large aircraft engines are more acute and some means must be provided to assure starting below plus 25°F.

Preheating and oil dilution are two methods widely used as starting aids for the large reciprocating aircraft engines. For many years civilian

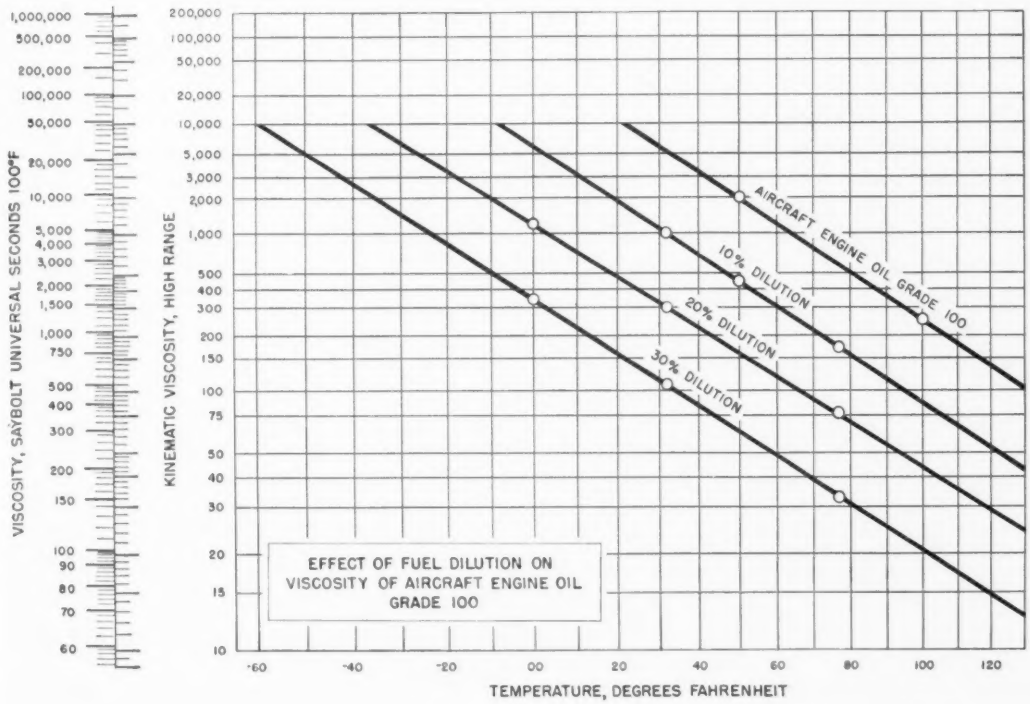


Figure 8 — Viscosity-Temperature Chart Showing the Effect of Fuel Dilution on Viscosity of Aircraft Engine Oil Grade 100.

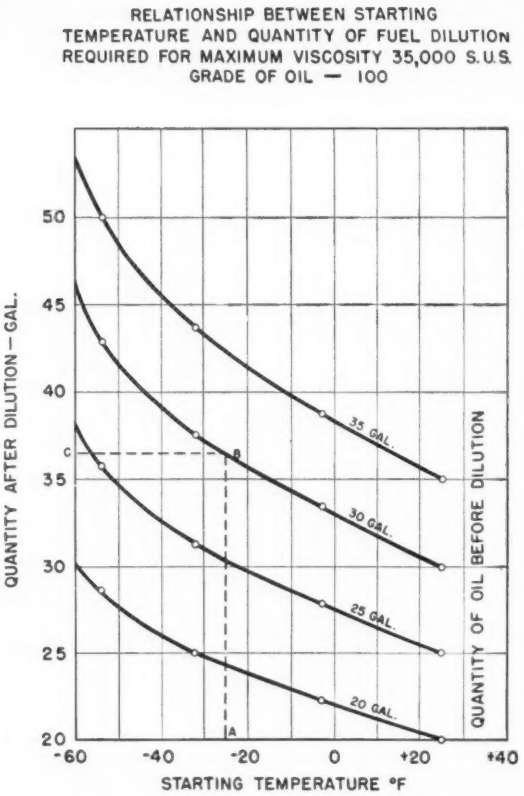


Figure 9 — Relationship between starting temperature and quantity of fuel dilution required for maximum viscosity of 35,000 S.U.S. with 100 grade of oil. Note: Before this plot can be used for any installation a correction should be made for quantity of residual oil remaining in engine and oil lines.

pilots in the north country drained their oil after each flight and kept it warm on a stove overnight. The next morning their practice would be to preheat the engine with the aid of a fire in an old oil drum and canvas tarpaulin and then pour in the warm oil. This method worked very successfully for the smaller types of aircraft. For military operations some other means appeared necessary due to the short time available to prepare for combat. Large size of multi-engine bombers and transports also made the "bush pilots' " technique rather awkward.

The development of the oil dilution system by the Air Force seems to have solved the cold starting problem insofar as lubricating oil is concerned. It has been used quite widely over the past few years on tactical and transport types of aircraft. While some improvements have been and are being made, its operation on the whole appears quite successful.

On Figure 8 there is plotted a group of viscosity temperature curves for grade 100 Aircraft Engine Oil and mixtures of this oil with 10, 20 and 30% fuel dilution. Once having established the maximum permissible oil viscosity for starting, this data shows the minimum permissible starting temperature and the per cent dilution required to accomplish starting at lower temperatures.

The procedure for diluting engine oil is to open a solenoid valve for a predetermined period admitting fuel to the lubricating oil as it enters the engine (Figure 6). It is essential that both engine and oil have been allowed to cool off. The oil inlet temperature should be below 50°C. (122°F.) prior to diluting otherwise evaporation of the diluent will be excessive. Normally a fixed time of dilution is given for the starting temperature anticipated. This applies only to that installation. The period will vary from about one to nine minutes.

Most systems employ a hopper in the oil tank into which the diluted return oil from the engine goes. When the engine is restarted at some later time the diluted oil circulates immediately to the engine and warms up the adjacent bulk oil in the remainder of the tank. As the engine warms up most of the diluent boils off within the first hour of operation.

In plain type oil tanks (without a hopper) with gages for measuring oil quantity, dilution may be accomplished by the quantity method using data from Figure 9. A pilot knowing first what minimum temperatures are anticipated will note the quantity of oil and dilute until the level of diluted oil reaches the desired quantity. (This chart does not make an allowance for the residual oil left in oil lines and engine. Since this will vary for each installation a corrected chart should be prepared for each case.) For example, let us assume that the lowest expected temperature will be minus 25°F. and the quantity of oil before dilution was 30 gallons. By projecting line A-B to the point of intersection on the 30 gallon curve and then across to point C it will be found that the quantity of diluted oil should come to 37 gallons, or an increase of 7 gallons. These data were determined from data on Figure 8 and assume that the maximum allowable viscosity is 35,000 seconds (Saybolt Universal).

Service Problems

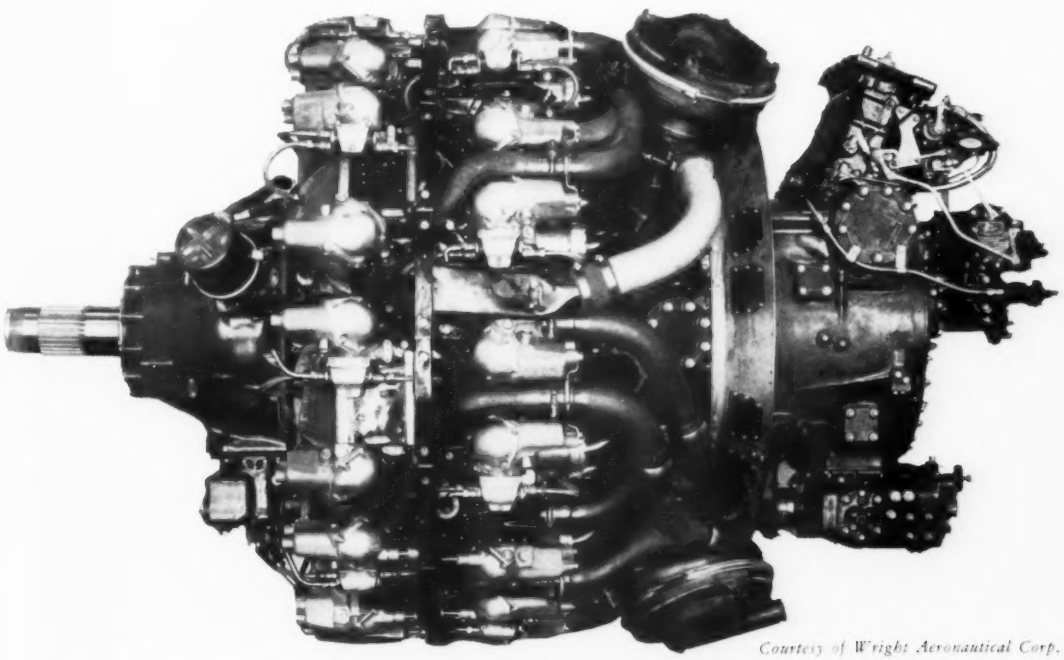
A majority of service problems relating to the external oil system, may be traced either to starting or operation at high altitude and extremely low atmospheric temperatures. Some of the more common problems of low temperature starting involve dilution of lubricating oil. Specifically, difficulties have been experienced on the proper control of the quantity of fuel used for dilution, evaporation of diluent, mixing of diluted oil in the hopper with the balance of the oil in the tank, and difficulties in driving off fuel following engine starting.

The most common method of controlling the quantity of fuel used to dilute lubricating oil, as already mentioned, is based upon time. For exam

ple, for a given system, 9 minutes of dilution may be required to achieve a dilution of 30%. This method is subject to wide variations at times, unless the same quantity of oil is maintained in the tank prior to dilution. Over-dilution can impair the reliability of an engine since it has been demonstrated that certain large aircraft engines are rather critical with respect to the minimum permissible oil viscosity. Also excessive dilution may loosen up engine deposits which are apt to clog oil passages and result in engine failure. If the dilution limits are exceeded failures may occur in master rod bearings, reduction gears, and scuffing of piston rings and cylinders. Some operators have failed to recognize the importance of diluting lubricating oil only after the oil had cooled down to below a specified temperature (50°C. maximum). Any attempt to dilute at higher than recommended oil and engine temperatures results in excessive evaporation of the fuel and may cause engine failure upon re-starting because of oil starvation.

Mixing of diluted oil in the hopper with undiluted oil from the outer tank has been reported as a common problem by the Air Force.[1] This is contrary to one of the functions of the hopper tank which is to segregate diluted oil from the undiluted oil. Flapper valves covering the openings connecting these two compartments have not been entirely satisfactory and have not prevented mixing of diluted and undiluted oil. When undiluted oil from the outer tank seeps into the diluted oil in the hopper and also into the oil inlet line (to the engine), engine failure may take place from lack of oil due to congealed oil in this line, and pre-heating of this section has been found desirable in many cases. This problem has made necessary certain improvements in the form of segregated oil tanks where a positively controlled poppet valve was installed between the outer tank and the hopper. It has been reported that proper dilution of lubricating oil now is possible with the segregated oil tank. Upon re-starting the engine, this control valve opens and as the oil in the outer reservoir warms up it may enter the hopper as required. The warm-up of oil in the outer tank has not worked as well as might be expected for the reason that the transfer of heat from the oil in the hopper to the remainder of oil is quite slow at very low temperatures and under extreme conditions heat may not be transferred more than a few inches from the hopper walls. Obviously, it then becomes necessary to make certain changes to assure more rapid warm-up of the undiluted oil, and also it may be necessary to insulate the exterior of the oil tank to reduce the heat radiation from the tank. In one case the Air Force[1] reported that following a start from minus 20°F., that after 30 minutes of operation, no heat was transferred farther than 3 inches from the walls of the hopper.

In one recent model of commercial transport air-



Courtesy of Wright Aeronautical Corp.

Figure 10 — Wright Turbo-Cyclone 18 Cylinder Compound Aircraft Engine. The first power plant of its type to be put into production.

craft, a plain oil tank is employed without a hopper. Dilution of the lubricating oil for cold starting is accomplished with the entire quantity of oil and not just a small portion such as is found in the hopper tank. Limited service experience with the non-hopper tank in the above model of aircraft has been very successful to date. In this case the tank is provided with an accurate oil level indicator and the practice is to note the quantity of oil in the tank at the start of dilution, and to dilute until the level is increased in an amount indicated by Figure 9.

Some reports have been received of cases where all of the fuel diluent did not evaporate. An example of this was found in the case of a certain transport that had diluted its lubricating oil prior to a transatlantic flight, and that upon completion of this flight, samples revealed as much as 4% diluent in the oil. It is possible that the remaining diluent might be traceable to either a leaking fuel dilution solenoid valve or to very cold operation of lubricating oil.

Operation of aircraft at extremely low atmospheric temperatures often introduces problems relating to water condensation in the oil tank, in Hydromatic propellers, and accumulations of ice in oil vent lines. It is well known that for every gallon of fuel consumed by an engine, more than one gallon of water is formed. Most of this water passes out the exhaust in the form of an invisible water vapor, but a small amount of it passes the rings and is picked up by the scavenging oil and returned to the oil tank. Service experience over a number of years in all types of aircraft has clearly demonstrated that unless certain oil temperatures are maintained in the oil tank, water may collect in sufficient quantities to cause serious service problems. The only way to eliminate water condensate in the oil tank is to maintain oil temperatures at a level where this water will pass out the vent in the form of vapor. Whenever oil temperatures in the tank have been allowed during operation to drop below approximately 130-140°F. substantial quantities of water may collect in the tank. This water is dangerous because it can seriously impair engine lubrication and it certainly will freeze if the aircraft is exposed to low temperatures between flights. Also, water and contaminants present in oil tanks will cause corrosion and damage to the bottom of these tanks. Likewise, corrosion has frequently been observed in propeller feathering pumps and in the domes of the Hydromatic propellers.

This is a problem that cannot be overemphasized, because it comes up again and again whenever designers overlook certain fundamentals and whenever operators are careless about maintaining recommended oil temperatures. The recommended minimum temperature of the oil entering the engine is approximately 155-175°F. with the dry sump system. Under no conditions should the temperature of the oil in the outer tank be allowed to get below 140°F., otherwise water accumulations and a host of other difficulties are certain to occur.

Freezing of water vapor in oil system vent lines has been observed in certain aircraft operating under conditions of extremely low temperatures. As long as reciprocating engines consume hydrocarbon type of fuels the formation of water is inevitable.

The designer is in the best position to overcome this problem by providing the shortest possible vent lines to eliminate condensation and freezing of the water vapor. In some cases heating of the vent lines by conductive material has proved quite satisfactory. Water and ice accumulations have been severe enough in some instances to completely block off the vent line, and when this occurs it may lead to rupture of oil tanks. The low points or traps where water might collect in the vent lines must be avoided.

CONCLUSION

From the foregoing, it is apparent that the successful operation of the aircraft engine depends to a large extent upon the proper design and operation of the oil system. As aircraft are built to operate at greater extremes of temperatures and under more and more severe conditions, much more attention must be paid to some of the details if the present high standards of reliability and low maintenance costs are to continue. Even though modern aircraft are operating under conditions today that were unheard of only a few years ago, the reliability and safety have increased substantially and this in itself is a tribute to the thoroughness and care behind the design as well as the operation of this equipment.

ERRATA

In the September 1950 issue of LUBRICATION which discussed "Grease Application Devices," Figure 8 on Page 102 was erroneously captioned as being descriptive of a Farval centralized lubricating system. This was an error. The photograph does not show a Farval system nor does it show the piping of the system. It simply shows what is known as a multiple tube installation which is not particularly related to any specific make of lubricating system.

[1] "Low Temperature Lubrication of Aircraft Engines," Saul Barron (Air Materiel Command), SAE Paper, January 1951.

Printed in U. S. A. by
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305 East 45th Street
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